

A Method to Enable High Contrast Imaging in Multiple Star Systems.

Completed Technology Project (2014 - 2016)



Project Introduction

We propose to demonstrate theoretically and experimentally a method to directly image planets and disks in multiple-star systems such as Alpha Centauri. This method works with almost any coronagraph or external occulter and requires little or no change to existing and mature coronagraph and wavefront control hardware. It also enables high contrast imaging beyond the outer working angle of a deformable mirror, enabling imaging of extended disks around single as well as multi-star systems. A (sun-like) star is $1e10$ times brighter than an Earth-like planet that may be orbiting around it. In any real telescope, diffraction and glare from that star completely swamp the planet. Several starlight suppression systems have been demonstrated in the lab that can remove the leakage of light from a star down to almost $1e10$ contrast. These systems employ a coronagraph to suppress the star diffraction and a wavefront control system based on a deformable mirror (DM) to remove residual starlight leak (speckles) created by the imperfections of telescope optics. However, this only works for single-star systems. Despite the ubiquity and importance of multi-star systems, little work has been done to date on how to directly image them, and they are typically excluded from mission target lists. We identified three main challenges associated with double-star (or multi-star) systems, and the objective of this proposal is to demonstrate each one in turn, first in simulation and then in the lab. The first challenge is that oftentimes multi-star separation is typically beyond the outer working angle (half-Nyquist frequency) of the deformable mirror. We will demonstrate a new method which we call 'Super-Nyquist Wavefront Control' where a mild grating (or an existing pattern commonly found on many DMs left over from their manufacturing process) effectively diffracts low-spatial frequency modes of the DM into higher frequencies, enabling the DM to remove speckles well beyond the DM's Nyquist frequency. In effect, this diffraction is used as a feature rather than a bug. The second challenge is to separate and independently remove overlapping speckles from multiple stars. We will solve this challenge by a new method we call 'Multi-Star Wavefront Control', which involves partitioning the correction zone and DM modes in a way that completely decouples the wavefront control of the two stars and enables simultaneously solving for both (at the expense of halving the discovery region). The third challenge is to combine the first two challenges simultaneously (which we call Multi-Star Super-Nyquist Wavefront Control), enabling high contrast imaging for multi-star systems with separations larger than the DM outer working angle. These three challenges will be demonstrated at the Ames Coronagraph Experiment (ACE) testbed at NASA ARC in monochromatic as well as broadband light. The main impact of this work is that it enables direct imaging of planetary systems and disks around multiple star systems as well as extends high contrast capability beyond the Nyquist-limited outer working angle of the DM, at essentially no additional hardware cost or changes to existing mission concepts, such as AFTA, Exo-C, and EXCEDE. This will greatly multiply the science yield of these missions. Furthermore, it potentially enables the detection of biomarkers on Earth-like



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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

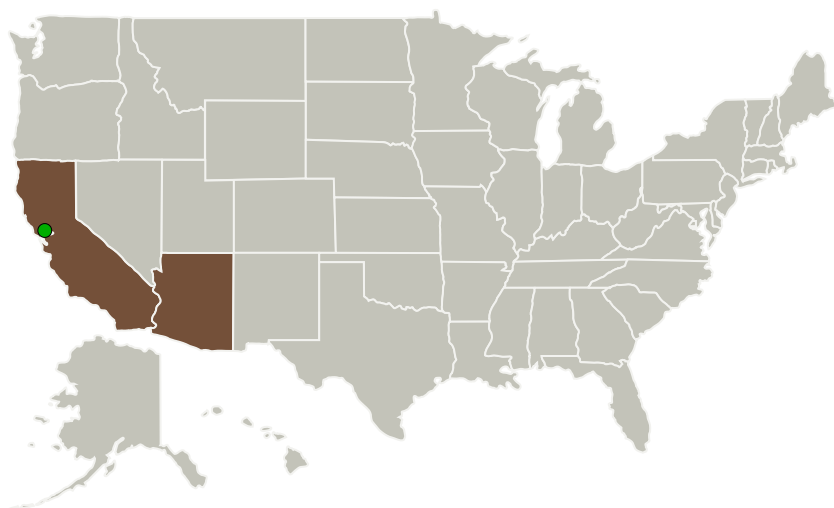
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planets (if they exist) around our nearest-neighbor star, Alpha Centauri, with a small and cheap space telescope or even a balloon, potentially decades sooner than a large space coronagraph could do the same around a single star system. The ability to directly image the aCen system in high contrast also enables the study of a planetary and disk system in much higher detail than for any other star, because aCen is a particularly low-hanging fruit many times closer and brighter than the next closest star of K-type or earlier.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
● Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California

Primary U.S. Work Locations	
Arizona	California

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

Ruslan Belikov

Co-Investigators:

Olivier Guyon
Yevgeniy Pluzhnyk
Eduardo A Bendek Selman
Sandrine J Thomas
Thomas Greene

Technology Areas

Primary:

- TX08 Sensors and Instruments
 - └ TX08.2 Observatories
 - └ TX08.2.1 Mirror Systems

Target Destination

Outside the Solar System